"CARDIAC CYCLE"

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CONTENTS

Definition

- Cardiac cycle is defined as the sequence of coordinated events which take place during heartbeat. Each heartbeat consists of two major periods called systole and diastole.

- During systole there is contraction of the cardiac muscle and pumping of blood from the heart through arteries.

- During diastole , there is relaxation of cardiac muscle and filling of blood. Various changes occur in different chambers of heart during each heartbeat. These changes are repeated during every heartbeat in a cyclic manner.

Divisions of cardiac cycle

- The contraction and relaxation of atria are called atrial systole and atrial diastole respectively. The contraction and relaxation of ventricles are called ventricular systole and ventricular diastole respectively.

- How ever, in clinical practice, the term 'systole' refers to ventricular systole and 'diastole' refers to ventricular diastole. Thus, the events of cardiac cycle classified in to two divisions.
- 1. Systole
- 2. Diastole.

Sub divisions and duration of cardiac cycle

- When the heart beats at the normal rate of 72/ minutes , the duration if each cardiac cycle is about 0.8 second. The duration of systole is 0.27 second and that of diastole is 0.53 second. Generally, systole is divided in to two sub divisions and diastole is divided in to five subdivisions.

systole

Time (second)
- 1. Isometric contraction   =   0.05
- 2. Ejection period   =   0.22

0.27

Diastole

Time(second)
- 1.Protodiastole   =   0.04
- 2. Isometric relaxation =   0.08
- 3. Rapid filling   =   0.11
- 4. Slow filling   =   0.19
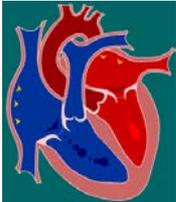- 5. Atrial systole   =   0.11

0.53

- The total duration of cardiac cycle is 0.27 + 0.53 = 0.8 second.

- Among the atrial events, systole occurs during the last phase of ventricular diastole. Atrial diastole is not considered as a separate phase, since it coincides with the ventricular systole and earlier part of ventricular diastole.

Description of events of cardiac cycle

- For the sake of better understanding, the description of events of cardiac cycle is commenced with atrial systole.

ATRIAL SYSTOLE - Heart

- The end of diastole
- Prior to atrial systole, blood has been flowing passively from the atrium into the ventricle through the open AV valve.
- During atrial systole the atrium contracts and tops off the volume in the ventricle with only a small amount of blood. Atrial contraction is complete before the ventricle begins to contract.

ATRIAL SYSTOLE
Pressures & Volumes

- The "a" wave occurs when the atrium contracts, increasing atrial pressure (yellow).
- Blood arriving at the heart cannot enter the atrium so it flows back up the jugular vein, causing the first discernible wave in the jugular venous pulse.
- Atrial pressure drops when the atria stop contracting.

ATRIAL SYSTOLE
ECG

- An impulse arising from the SA node results in depolarization and contraction of the atria (the right atrium contracts slightly before the left atrium).
- The P wave is due to this atrial depolarization.
- The PR segment is electrically quiet as the depolarization proceeds to the AV node.
- This brief pause before contraction allows the ventricles to fill completely with blood.

ATRIAL SYSTOLE
Heart Sounds

- A fourth heart sound (S4) is abnormal and is associated with the end of atrial emptying after atrial contraction.
- It occurs with hypertrophic congestive heart failure, massive pulmonary embolism, tricuspid incompetence, or cor pulmonale.

ISOVOLUMETRIC CONTRACTION
Heart

- The Beginning of systole
- The atrioventricular (AV) valves close at the beginning of this phase.
- Electrically, ventricular systole is defined as the interval between the QRS complex and the end of the T wave (the Q-T interval).
- Mechanically, ventricular systole is defined as the interval between the closing of the AV valves and the opening of the semilunar valves (aortic and pulmonary valves).

ISOVOLUMETRIC CONTRACTION
Pressures & Volumes

- The AV valves close when the pressure in the ventricles (red) exceeds the pressure in the atria (yellow).
- As the ventricles contract isovolumetrically -- their volume does not change (white) -- the pressure inside increases, approaching the pressure in the aorta and pulmonary arteries (green).

ISOVOLUMETRIC CONTRACTION
ECG

- The electrical impulse propagates from the AV node through the His bundle and Purkinje system to allow the ventricles to contract from the apex of the heart towards the base.
- The QRS complex is due to ventricular depolarization, and it marks the beginning of ventricular systole. It is so large that it masks the underlying atrial repolarization signal. the ventricles to fill completely with blood.
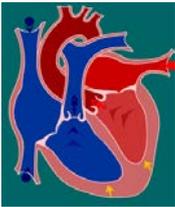
ISOVOLUMETRIC CONTRACTION
Heart Sounds

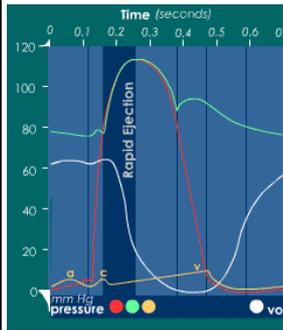- The first heart sound (S1, "lub") is due to the closing AV valves and associated blood turbulence.
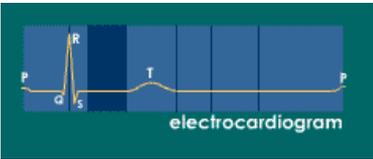
RAPID EJECTION

RAPID EJECTION
Heart

- The semilunar (aortic and pulmonary) valves open at the beginning of this phase.

RAPID EJECTION
Pressures & Volumes

- While the ventricles continue contracting, the pressure in the ventricles (red) exceeds the pressure in the aorta and pulmonary arteries (green); the semilunar valves open, blood exits the ventricles, and the volume in the ventricles decreases rapidly (white).
- As more blood enters the arteries, pressure there builds until the flow of blood reaches a peak.
- The "c" wave of atrial pressure is not normally discernible in the jugular venous pulse. Right ventricular contraction pushes the tricuspid valve into the atrium and increases atrial pressure, creating a small wave into the jugular vein. It is normally simultaneous with the carotid pulse.
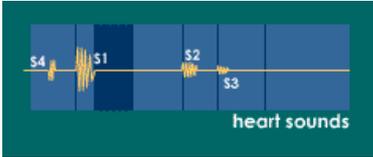
RAPID EJECTION
ECG
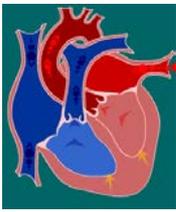

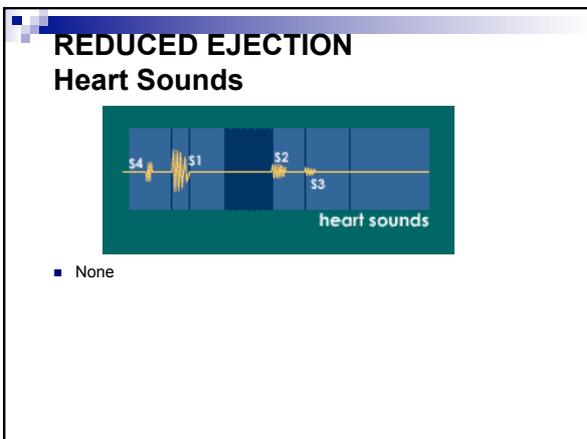- No Deflections

RAPID EJECTION
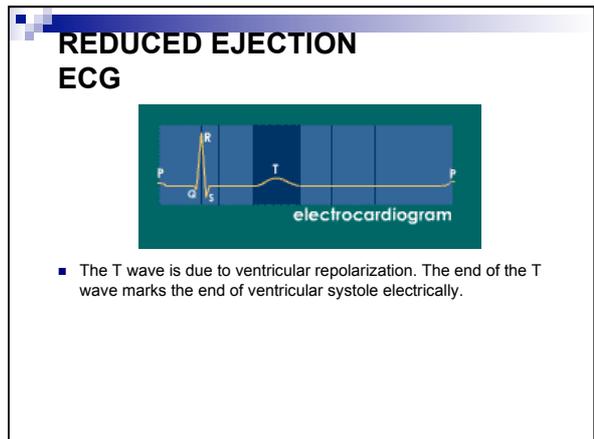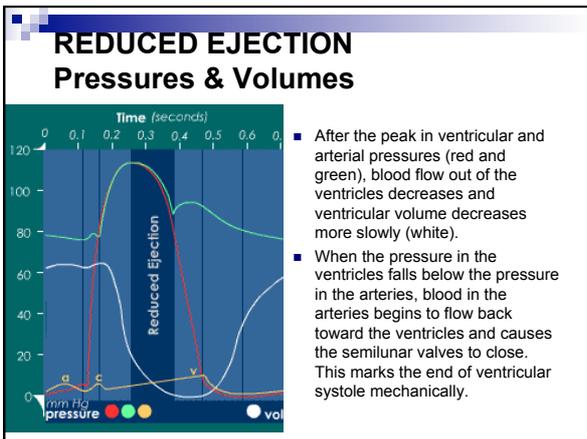### Heart Sounds

- None

REDUCED EJECTION

The end of systole

REDUCED EJECTION
Heart

- At the end of this phase the semilunar (aortic and pulmonary) valves close.

REDUCED EJECTION
Pressures & Volumes

- After the peak in ventricular and arterial pressures (red and green), blood flow out of the ventricles decreases and ventricular volume decreases more slowly (white).
- When the pressure in the ventricles falls below the pressure in the arteries, blood in the arteries begins to flow back toward the ventricles and causes the semilunar valves to close. This marks the end of ventricular systole mechanically.

REDUCED EJECTION
ECG

- The T wave is due to ventricular repolarization. The end of the T wave marks the end of ventricular systole electrically.

REDUCED EJECTION
Heart Sounds

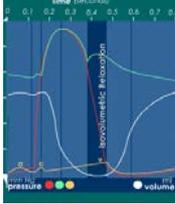- None

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ISOVOLUMETRIC RELAXATION

The beginning of Diastole
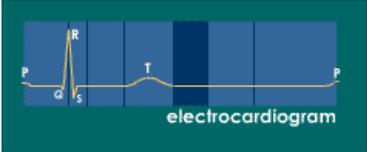
ISOVOLUMETRIC RELAXATION
Heart
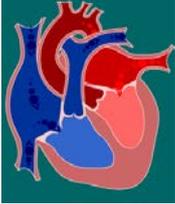
- At the beginning of this phase the AV valves are closed.

ISOVOLUMETRIC RELAXATION
Pressures & Volumes

- Throughout this and the previous two phases, the atrium in diastole has been filling with blood on top of the closed AV valve, causing atrial pressure to rise gradually (yellow).
- The "v" wave is due to the back flow of blood after it hits the closed AV valve. It is the second discernible wave of the jugular venous pulse.
- The pressure in the ventricles (red) continues to drop.
- Ventricular volume (white) is at a minimum and is ready to be filled again with blood.
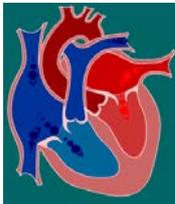
ISOVOLUMETRIC RELAXATION
ECG

- No Deflections
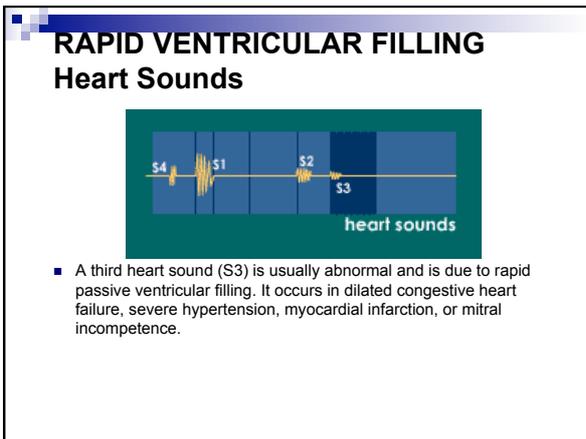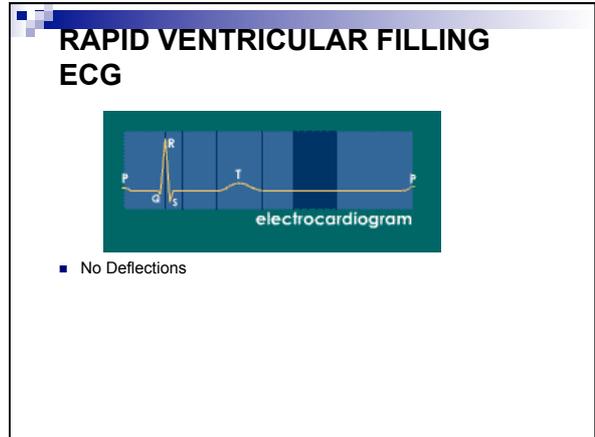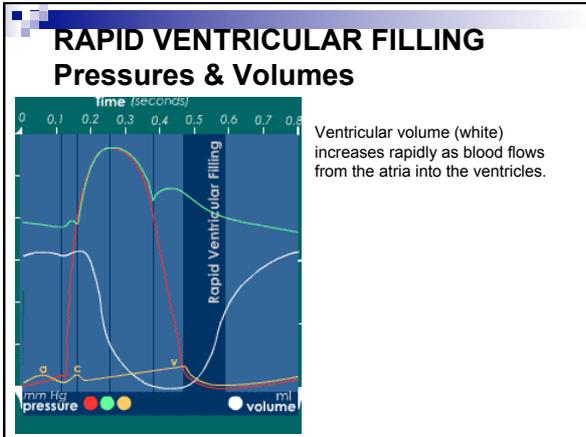
ISOVOLUMETRIC RELAXATION
Heart Sounds

- The second heart sound (S2, "dup") occurs when the semilunar (aortic and pulmonary) valves close. S2 is normally split because the aortic valve closes slightly earlier than the pulmonary valve.
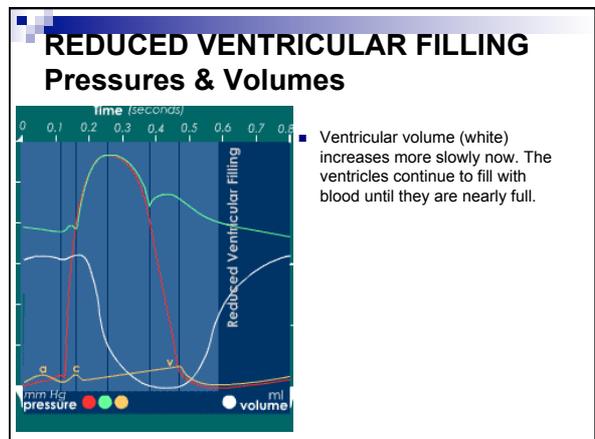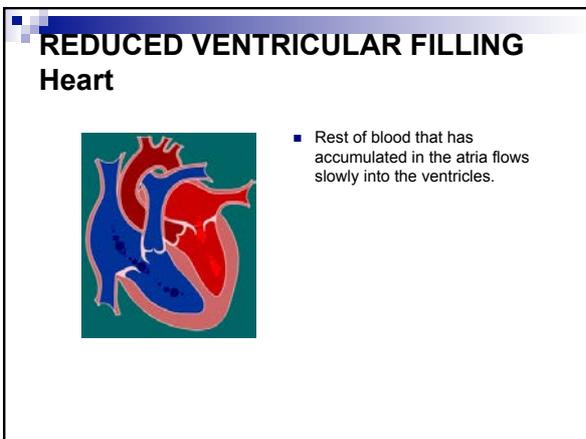
RAPID VENTRICULAR FILLING
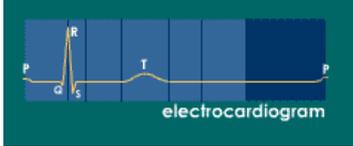
RAPID VENTRICULAR FILLING
Heart

- Once the AV valves open, blood that has accumulated in the atria flows rapidly into the ventricles.

RAPID VENTRICULAR FILLING
Pressures & Volumes

Ventricular volume (white) increases rapidly as blood flows from the atria into the ventricles.

RAPID VENTRICULAR FILLING
ECG

- No Deflections

RAPID VENTRICULAR FILLING
Heart Sounds

- A third heart sound (S3) is usually abnormal and is due to rapid passive ventricular filling. It occurs in dilated congestive heart failure, severe hypertension, myocardial infarction, or mitral incompetence.

REDUCED VENTRICULAR FILLING

(Diastasis)

REDUCED VENTRICULAR FILLING
Heart

- Rest of blood that has accumulated in the atria flows slowly into the ventricles.

REDUCED VENTRICULAR FILLING
Pressures & Volumes

- Ventricular volume (white) increases more slowly now. The ventricles continue to fill with blood until they are nearly full.

REDUCED VENTRICULAR FILLING
ECG

- No Deflections

REDUCED VENTRICULAR FILLING
Heart Sounds

- None

THE COMPLETE PICTURE

The Cardiac Cycle

- Cardiac cycle refers to all events associated with blood flow through the heart from the start of one heartbeat to the beginning of the next
- During a cardiac cycle
  - Each heart chamber goes through systole and diastole
  - Correct pressure relationships are dependent on careful timing of contractions

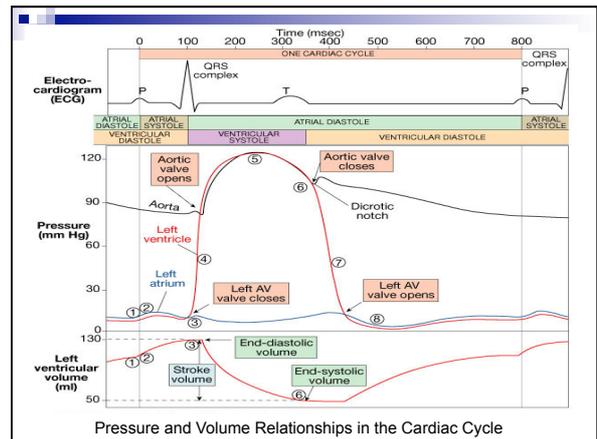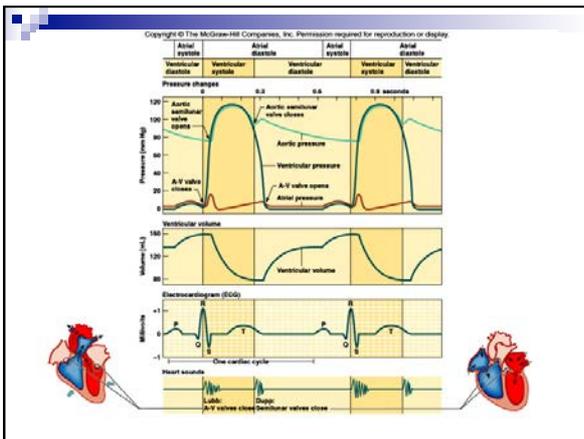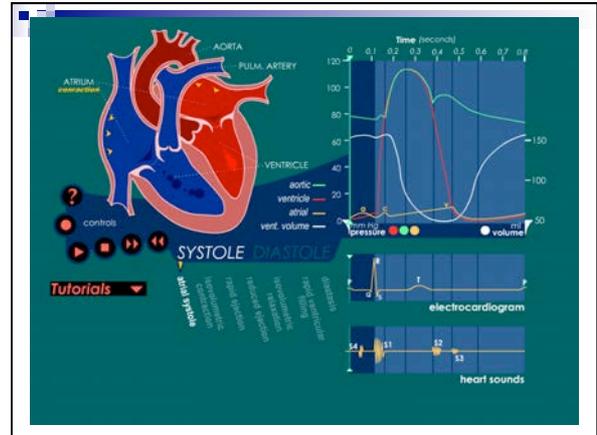# Phases of the Cardiac Cycle

- Atrial diastole and systole -
  - Blood flows into and passively out of atria (80% of total)
    - AV valves open
  - Atrial systole pumps only about 20% of blood into ventricles
- Ventricular filling: mid-to-late diastole
  - Heart blood pressure is low as blood enters atria and flows into ventricles
  - 80% of blood enters ventricles *passively*
  - AV valves are open, then atrial systole occurs
  - Atrial systole pumps remaining 20% of blood into ventricles

Phases of the Cardiac Cycle

- Ventricular systole
  - Atria relax
  - Rising ventricular pressure results in closing of AV valves (1st heart sound - 'lubb')
  - Isovolumetric contraction phase
    - Ventricles are contracting but no blood is leaving
    - Ventricular pressure not great enough to open semilunar valves
  - *Ventricular ejection* phase opens semilunar valves
    - Ventricular pressure now greater than pressure in arteries (aorta and pulmonary trunk)
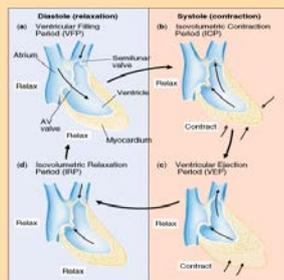
Phases of the Cardiac Cycle

- Ventricular diastole
  - Ventricles relax
  - Backflow of blood in aorta and pulmonary trunk closes semilunar valves (2nd hear sound - "dubb
    - Dicrotic notch – brief rise in aortic pressure caused by backflow of blood rebounding off semilunar valves
  - Blood once again flowing into relaxed atria and passively into ventricles

Pressure and Volume Relationships in the Cardiac Cycle

PERIODS OF THE CARDIAC CYCLE

▶ Periods of the Cardiac Cycle

SUMMARY

▶ Summary of the Cardiac Cycle